MAXINE SINGER

MOYERS: Many years ago, the popular image of the scientist was either Dr. Frankenstein or Dr. Strangelove. You were either creating monsters you couldn't control, or you were plotting to blow up the world. Do you think that image still prevails?

SINGER: It still prevails in many places. I experience it personally. People meet me casually at dinners or parties and ask what I do. When I say, "I'm a molecular biologist," they go to the far end of the room. I suppose they're puzzled by the fact that I don't look or act like Dr. Frankenstein. But they somehow are frightened and think that I must live in a world apart, without the same kind of human concerns they have.

MOYERS: Perhaps they're ashamed, as I often am, of their ignorance of the field, and unable to talk to you about it. So they politely shift the conversation to somebody else who can talk about the weather or politics.

SINGER: That's certainly true, because people do apologize and then, of course, to be polite, I say, oh, don't worry about that, I don't know about whatever it is you know about. But, in fact, I've given up accepting those apologies. I'm much more forthright now. I tell them that I'm sorry for what they don't know, but it's never too late to learn.

MOYERS: What does it say to you that our society has such a negative image of scientists?

SINGER: It says that science was not an integral part of most

people's upbringing and education. As they were growing up, they didn't come to understand that science was one of the grand human activities. It uses the same kind of talent and creativity as painting pictures and making sculptures. It's not really very different, except that you do it from a base of technical knowledge.

Science is not an inhuman or superhuman activity. It's something that humans invented, and it speaks to one of our great needs--to understand the world around us. In the end, it makes you wonder whether people have lost their curiosity, because that's all it is.

MOYERS: Given the negative image of scientists, why did you as a young woman decide to become one?

SINGER: I'll give you the answer that, in fact, many, many scientists give when asked this question. I had one marvelous chemistry teacher in high school. She was an exciting teacher, interested in me because I was interested in what she taught, and very demanding.

MOYERS: That's not a term you hear about many teachers these days, I'm sorry to say. In fact, since I called you and asked you to do this interview, there was another report saying that kids coming out of high schools are increasingly scientifically illiterate.

SINGER: It would be difficult to give a good scientific education without being demanding. There's a certain amount of hard work, but the pay-off is marvelous, because when you do the hard work and come to understand something about the way the world works, then the satisfaction is so enormous that it makes you willing to do more demanding work. But if the hard, intellectual work to understand is not demanded of you, then you can't have the pleasure of it either.

Let me tell you a story that goes back to the days when my now

grown-up children went to junior high school. Each of them in turn came into a biology class that was taught by a superb teacher. Within two weeks of the beginning of the school year, on each of those four occasions, I began to get calls from parents of other children in the class asking whether I would join a delegation to the principal, to complain about the amount of work that this biology teacher gave. The parents thought she gave too much homework. They also didn't think biology was that important. They were shocked to learn that I wouldn't join the delegation. Now these parents were highly educated and had great expectations for their children, although none of those expectations included science. They just didn't feel that it was worth the effort that was being demanded of their children.

MOYERS: This happened not just with one child of yours?

SINGER: It happened each time, four times in a row. The parents didn't see the opportunities in being a scientist. They didn't understand the profound importance of scientific discovery and technical competence to the society in which they live. I think their response also indicated that they thought there was a free lunch out there, which there isn't. It was a very depressing experience.

MOYERS: What happens to a society where the curiosity goes, and scientists are seen as marginal at best, and wasteful at worst?

SINGER: On any day, if you look at the front page, half the stories usually have a technical or scientific component in them. A society that turns its back on science has to face decay and deterioration.

There are people who romanticize, who say, wouldn't it be nice to go back to the lovely old days when we didn't have pollution problems? In a way it would--but we can't. We have a much larger population on the

globe.

Those days weren't so terrific either. Many, many infants died within the first week of birth. Very few people lived the nice long lives that we're living now. Very few people could visit different parts of the globe. Everybody seems to want the fruits of science, and everyone recognizes that those fruits have a cost. ~~and that there are~~ But the new problems ~~that~~ will not be resolved unless we deal with them in a scientific way. We must advance new knowledge so that we have more ideas about how to deal with the continually new problems that we have.

MOYERS: When you look at the 21st century, which is not that far away now, what are the scientific problems you think a republic like ours is going to have to face?

SINGER: We're going to have to face population problems in our republic and all over the world. And we're going to have to face them as we always face major problems, by a combination of things, including limiting the population and dealing with some of the very difficult issues that arise when we have a large population.

MOYERS: And science is at the heart of that issue?

SINGER: Science is at the heart of how we will continue to grow enough food for all of these people. We're not doing it now. There are people starving all over the world, and the answer is scientific agriculture. A lot of the answers will come from the advances in my own field of genetics and molecular biology. We're coming to a really extraordinarily deep understanding of the way living things work, and of how to manipulate them properly, so that we can improve food production in Africa, for example.

Our environmental problems are to a very large extent derivative of

population problems. We're constantly expanding the places that we need to live, so that we're tearing down forests, destroying natural wetlands and savannahs--changing the nature of our planet in order to accommodate this ever-increasing population which is, at the same time, increasing its expectations for how it's going to live.

Transportation is another problem we must address as we spread populations out. People need to be moved around faster and yet, at the same time, without doing further destruction to the environment.

MOYERS: We think of these as political issues, and of course they are. But you're saying that there's a scientific core that has to be addressed if we're going to resolve them.

SINGER: The political decisions--to the extent that political decisions deal with reality, which they don't always do--will be made on the basis of options that are provided by scientific discoveries and the technological development of those discoveries. One of the things that stems from this is that there is more power in the scientific community than many people realize. Many people default to the scientific community.

MOYERS: What do you mean?

SINGER: They leave the options that will eventually inform the political decisions to the scientists, because people are unwilling to include science as part of their general education.

MOYERS: How do we make an informed choice if we don't know at least the basic vocabulary?

SINGER: The only way we can do it is the way every study of the last dozen years has told us. We insist that our young people learn science. We insist that teachers not turn kids off science. Getting young children

interested in science is the easiest thing in the world. You go outside at night and look at the moon, and outside during the day and look at the sun, and then you ask children, "What is our relation to the moon and sun?" You take them down to the air and space museum and show them what the earth looks like if you're up at the moon, which we can do now, because we've been there, and the children begin to generate the same questions that astronomers generate. Then you begin to talk to them about how you learn the answers, and they're engaged. But somewhere between the fourth and fifth grade, something happens. We lose them. We kill that creative curiosity.

There is a fear of science and scientists. It's strange to me that people don't realize that the way to deal with that fear is to learn about it. We scientists are not very fearful people. We look upon the world in a somewhat different way, but we show the same good and bad traits as everyone else. The negative things about scientists are the same as the negative things about anyone else. There's a lesson to be learned there, because if people would talk to us and learn what we're like, they would realize this, and they would then be less afraid of science. But a lot of people don't want to talk about scientific issues. They draw very firm lines.

MOYERS: Don't you think they say, "Let's let Maxine Singer handle it. Let's let the scientists do it."

SINGER: Well, they do and they don't, because eventually it comes knocking on their door. One of the very good examples of this in our society is the constant trouble we have had for forty or fifty years with the notion of evolution. Every couple of years, this becomes an issue in American schools, and we fight this battle all over again. There are people who have a very fundamental belief in the Bible as a description of

the world and as essentially a scientific document, but they represent a very small percentage of the population. Yet more than fifty percent of Americans, when asked year after year, say they believe that creationism should be taught along with evolution in the schools. That's an amazing number. It tells us that over fifty percent of Americans, and that includes a lot of very highly educated Americans, are very uneasy about the notion of evolution. I think it's because they think that if we accept the theory of evolution, we somehow leave behind a lot of the premises on which our human interactions are based.

MOYERS: Religious folks say that the work of people like Maxine Singer establishes the relationship of everything to a common ancestor, that genetics confirms evolutionary biology, and that it leads to a profoundly mechanistic view of the world, in which there is no room for God. That's part of the fear leading to the determination that creationism will be taught in the high schools along with evolution.

SINGER: It is true that modern genetics has confirmed all of the ideas of evolutionary biology. A very famous geneticist said, many years ago, that there was no way to think about the natural world that made any sense except in terms of evolution. If you try to think about the living world without the concept of evolution, it would be something like teaching lawyers to be lawyers without reference to the United States Constitution. We only think about law in our country in the framework of our Constitution. Biologists can only think about the living world in the framework of evolution. And modern genetics has confirmed that. People fear the challenge of a mechanistic view of life, and that is indeed what modern genetics teaches us--a very mechanistic view of life.

MOYERS: And a mechanistic view means--

SINGER: It means that if you look at a corn plant, you want to explain how the corn plant grows, why it puts out an ear of corn that's yellow, or red, why it grows well with a certain amount of water, what you can do to make it grow better during drought--in other words, you explain the corn plant as you would a machine. We can do that in terms of the molecules that make up the corn plant.

MOYERS: You say it is mechanical, but not like the movement of a clock.

SINGER: No, it's much more flexible than that. A lot of things are changing as part and parcel of the whole system. We know that the simplest organisms on our planet are the same as we are, in terms of being what they are because of DNA molecules that are not very different from our own. We can speak of a common origin someplace at the beginning.

MOYERS: You mean the same thing is in the yeast that is in the human being.

SINGER: In fact, you can take a human gene, and it will correct a mutation in a yeast cell.

MOYERS: What does that mean?

SINGER: That means that a piece of DNA from human cells, when added to the DNA of the yeast cell--the same yeast that we use to bake our bread and make our wine--can actually be therapeutic for a yeast cell that's sick because of a bad gene. What we're doing is gene therapy on yeast. We have a sick yeast cell because it has a genetic disease. And we can cure the yeast cell's genetic disease with a human gene. That tells us that we have a lot in common with the yeast cell. The same is true for all kinds of organisms. Yeast is the most dramatic example, because it's a simple one-celled organism.

MOYERS: Well, what that says to the fundamentalist is that what God hath wrought, Maxine Singer can put asunder. It destroys the Psalmist's vision--"What is man, that Thou has made him a little lesser than the angels."

SINGER: I don't think it destroys the Psalmist's vision at all. The Psalmist was talking about man, and man remains that way. Our relations with one another and with our society remain quite separate from our ability to understand how we work. Ancient people were just as curious as we were about where the stars came from, and where we came from. They made explanations in terms of what they knew, and they tied their explanations together with expectations about standards of human behavior and notions of human love. We're changing the explanations, but we're not really changing those other things. There are a couple of pieces of evidence for that. There are among scientists deeply religious people in about the same proportion as in the rest of society. There are people who adhere to the highest standards of human conduct, and there are people who are as greedy and money-grubbing as anywhere else, in spite of the fact that we look to natural explanations.

MOYERS: So science doesn't change the essential qualities of human beings, their love for justice, or their passion for greed, or their sense of fairness, or their sense of alienation?

SINGER: What it changes are the old explanations and rationalizations for the way [redacted] things occurred, but it doesn't change our fundamental human problems or the way we deal with each other. What it does, fundamentally, is give us ways to deal with the difficult things that we find on the planet and ways to enhance our lives. Think of what your life would be without the marvelous ability to have terrific music in

your own home. In genetics, we will have ways to deal with diseases which now confound us and cause nothing but misery. We will have ways to deal with diseases that we almost don't recognize yet, including propensities toward certain diseases. We'll be able to deal with those things, because we're beginning to understand the way we work, the way the corn that feeds us works, and the way elements that cause disease work. ~~We all~~ Remarkably, all these living things work in fundamentally the same way.

MOYERS: What are you working on right now in your research?

SINGER: I'm interested in human genetics, particularly in aspects of the structure of human DNA, what we call the human genome. "Genome" is just a collective word for all the DNA in the human cell. The whole collection of genes and other pieces of DNA that are not genes make up the human genome.

MOYERS: Now just so that a scientifically illiterate journalist would understand the analogy--would it be right to say that the gene is to the human makeup as the thread in this suit is to the suit?

SINGER: No, the best way to look at it is that a gene is like a sentence in an encyclopedia. It's a piece of information buried in the genome, the whole encyclopedia, which is a vast store of information. The gene instructs the cell how to do some one thing. All together, the ~~billions~~ trillions of cells in your body do all the things that make you who you are, and that make a corn plant what it is, and that make a yeast cell what it is.

MOYERS: So the better analogy would be perhaps that it's like a chip.

SINGER: It's a chip--but ~~we could use~~ I prefer the old-fashioned analogy of a book--like an encyclopedia, or a sentence that gives you a piece of

information.

MOYERS: What are you trying to explore about it?

SINGER: Well, in fact, what my colleagues and I in my lab do is not quite looking at what a gene is like. It turns out that a lot of DNA doesn't clearly have any information, at least as far as we know now. It's as though you had an encyclopedia, and on every third page there was a lot of jabberwock. And then you turned six more pages, and you repeated exactly the same jabberwock again--and two pages later, there it was again. It doesn't look like a gene--that is to say, it doesn't look like a meaningful sentence. I can't figure out what it is. And I'm certainly confounded by the fact that it occurs so many times. My colleagues and I are looking at a ~~sentence~~ DNA segment in the human genome that occurs probably on the order of 100,000 times, and altogether makes up about five percent of the DNA in every cell. Why? We don't know. What is it doing? We don't know. We do know that new copies of it can be made in ~~the~~ a human cell and put in a new place in the DNA. And we know, thanks to the work of some human geneticists at Johns Hopkins, that it can cause mutations. That was a very exciting finding in the last year for us, because it says that this piece of genomic jabberwock can pick itself up from one place in the genome and settle down somewhere else, where it can cause a mutation--in this particular case, two instances of the disease of hemophilia. So, it's very real and very serious.

MOYERS: What is the value of finding this out?

SINGER: The value is severalfold. First of all, if we can understand what makes such a sequence move about, we will have understood the cause of a certain amount of genetic disease. We will be able to understand the role of flexibility in the DNA molecule. The analogy to

the encyclopedia falls down once you realize that DNA moves itself about and changes in all of us, all the time. That's one of the things that we'll learn from this human genome project.

MOYERS: There's a lot of talk in this city about the human genome project, which will cost billions of dollars. What is it?

SINGER: To continue the analogy I've been using, it would be equivalent to saying that we could write out the encyclopedia for human DNA, and that we would know all of the information in a human cell. We would know how to find it, as we do when we look in an index of an encyclopedia, or when we look up something alphabetically. We would know how to turn to the gene that causes hemophilia when it's mutated. We would know how to turn to the page that says this gene is going to be important in causing a certain tumor. We would know how to look at that gene in a person, and perhaps make some guesses as to whether that person is likely to develop a certain tumor or not.

MOYERS: So if you knew that, then you could begin to think about altering the gene to prevent the disease.

SINGER: The genome project is defined very grandly. It will do a lot of things along the way. It will tell us a lot about the genomes in other species, because one of the ways we'll do the human genome project is by comparison with plants and yeast cells. One element of science is comparison. You learn a tremendous amount by comparing two things. This is like that, or this is not like that. Why is it not like that? And what can we learn?

MOYERS: But why should the public buy into this project with such vast sums of money? It will cost two or three billion dollars.

SINGER: Those sums of money are going to be spent over a long period

of time. But the nice answer to your question, the grand and glorious answer, is because the public is curious about itself, as curious as we are. We scientists will do the work, but we will all share in the understanding that it gives us about ourselves and the world we live in. The public will also be interested because it is with that knowledge that we're going to be better able to deal with starvation, to learn how to grow plants in Africa that can't now be grown there. We're going to learn how to deal with certain diseases. We will improve the lot of all mankind.

MOYERS: --New cures for cancer? New vaccines?

SINGER: --Eventually new cures for cancer, new vaccines, and things unimaginable to us now, but which we know we will learn by doing this. We can't even describe them. The reason we know that we will discover things that we can't describe now is that this has been the history of science. We do things to learn something we can define, and we wind up knowing things we never imagined even asking about.

MOYERS: A lot of us are nervous about the whole idea of genetic engineering. We're not sure we should be fooling around with our genes.

SINGER: Why aren't you sure? What bothers you?

MOYERS: I'll show you a picture from The Economist that illustrates what scares people.

SINGER: Okay.

MOYERS: That's a picture of what's called a geep. A scientist at Cambridge University crossed the embryos of a goat and a sheep and got a three-legged geep. People see this and imagine a future of horrible mutilations, of something beyond human beings. That's one part of it.

SINGER: The geep is something that someone did in order to learn whether it could be done, but it's not something that people are going to

be making, except on an occasional experimental basis. And it is surely not something that will ever be done with human beings in any similar way.

MOYERS: How can you say that with such certainty?

SINGER: Because scientists are human beings, as human as those who are not scientists. They share the same values. The greatest resistance to doing any genetic engineering on human beings has come from the scientific community. There are very strong feelings within the scientific community about doing genetic engineering on human beings. And the evidence for that is the level of review and discussion within the scientific community prior to doing even very small things--nothing that comes even close to a geep. I talked before about correcting a mutation in a yeast cell. We can imagine ways of correcting human mutations, and people are trying to devise ways to do that as therapeutic devices. That's not really very different from therapies that we've used before because they're designed to correct a certain disease. But it's very different in that it will be much more precise and effective, and will be a better cure.

But even before thinking about that, there has been an extraordinary level of conversation in the scientific community as well as in gatherings of people from outside the community to come to some general notion about what we think is useful to do--what is human, and what is humane, and what is something that no one would ever do.

MOYERS: But in the end, the scientific community is not itself responsible for what happens to its discoveries. Your faith in humanity is touching. It may be more so than the journalist's. But when engineers created the oven, I don't think they expected a Christian nation in the heart of Europe to put millions of human beings to death in them.

SINGER: What you're saying is something I would agree with. If the knowledge that is gained is misused, it is not because of science or the scientist, it is because of the same old human problems that have caused evil for eons.

MOYERS: There's a will to use what we know.

SINGER: And whether evil uses technology that's new or technology that's old, what motivates it are human problems that have nothing to do with the developments in technology. To make technological and scientific development the scapegoat because it gives evil people new tools to do evil seems to be missing the boat. To the extent that the traditional ways of defining moral behavior have failed, the newer ways will fail, too, because human beings will remain the way they are.

MOYERS: Then what do we do about this? Because if we learn how to transplant genes and to alter the genetic code, shouldn't there be some standards for the use of that knowledge?

SINGER: Of course there should be standards. Several of my colleagues and I spent the better part of a decade in the seventies working on standards for the very earliest genetic engineering experiments at a time when our concerns were not about misuses of human gene therapy, but about the safety of the things that would be constructed. Scientists now are spending enormous amounts of time trying to inform publicly responsible individuals and groups about the nature of what we're doing so that people can figure out what the standards ought to be. But if we simply say no to everything, then we turn our backs on our abilities to solve the very real problems that we have.

MOYERS: What do you see personally and scientifically as the dangers in genetic engineering?

SINGER: I don't actually see dangers in gene therapy for genetic diseases as long as they are carried out under the general kinds of standards that we have come to apply to medical interventions in general--that the research should go on after review by knowledgeable scientists and non-scientists; that things are done with the consent of those on whom new practices are tried; that they are done in the context of institutions which provide guidelines and monitoring of what happens in the hospital and the laboratory.

That's the way we have to do it. It's hard work. It's time-consuming. But it should help us derive the benefits that we want in so many ways, and yet limit the possible dangers.

MOYERS: An interesting poll not long ago showed that forty percent of the people in this country said they thought it was morally wrong to alter the genetic code, but eighty percent of them went on to say that they would be willing to risk it if they thought taking that risk might prevent a disease they had themselves.

SINGER: I find those polls very puzzling. What they tell me is that people lack an understanding of the sciences. The people who say, "I just don't think it's right to meddle with these genes in this way" don't understand enough about what we're doing to be able to sort out for themselves what's right or wrong about it. In my judgment, there's nothing profoundly wrong about it. We're been fooling with genes since the beginning of time by breeding farm animals and plants for better yields. In ancient times, and even now in some cultures, mates are chosen for young people on the basis of what the family thinks the grandchildren will be like. That's breeding human beings, and that's accepted. We're just learning how to do things a little better and in a more humane way.

People used to think that disease was a punishment. Smallpox, for example, was viewed as a punishment for evil deeds that people did.

MOYERS: Yes, there was a man named John Woolman.

SINGER: Yes, a famous ~~old~~ 18th Century member of the Society of Friends, a marvelous man--but he believed that smallpox came from God.

MOYERS: --to instruct humans in virtue. Woolman was the same man who was so opposed to slavery.

SINGER: Exactly. There are people now who believe that AIDS represents the same kind of punishment. But smallpox didn't come as a punishment to human beings, it evolved on the face of the earth with the rest of us. It evolved, in fact, in conjunction with man. It lived off man. We have killed the smallpox virus. We don't have it anymore on the face of the earth.

MOYERS: I've often wondered, if John Woolman came back today, whether he would think that God had changed His mind.

SINGER: We are much better off for the absence of smallpox, and we have not paid any price for its absence. There are people to this day who look upon AIDS as a punishment. It's not. It's caused by a virus whose structure we can describe in such a way that we can think about it rationally and try to figure out ways to end the scourge that it has brought on our society. These are the kinds of things that come only from science.

MOYERS: You know, I hear you, and I believe you, but there are common concerns out there that people keep telling me about genetic engineering. Now these concerns may come out of a great ignorance, including the ignorance and superficiality of journalism. But you hear people saying, "Well, will it be possible for parents to seek hormones

that will produce a seven-foot basketball player so that I can raise my kid to go out there and make money as a professional athlete?"

SINGER: Yes, it is possible to do that. You can do that today without any genetic engineering of humans, because genetic engineering has made growth hormone available cheaply. We need the growth hormone to treat people who are diseased in the sense that they don't make it themselves. It's available, and it's cheap. But people are buying it to give to their children to make them good athletes. That's not a problem of the scientist who cloned the human growth hormone gene in order to help children who suffer from an absence of it and would be dwarves otherwise. The problem is the same old human problem of greedy, thoughtless parents who are using something to achieve an end that the scientists who developed it never dreamt of.

MOYERS: We're back to ethics.

SINGER: We're back to ethics, but not the ethics of scientists, except insofar as they're people like anyone else.

MOYERS: What about the weightier concern I've heard in some quarters that if we start manipulating genes for profit, we will be giving a powerful economic incentive to seeing of human nature as essentially a materialistic phenomenon.

SINGER: I must tell you, straight out--I think it's bunk.

MOYERS: Don't mince your words.

SINGER: Let me put it to you this way: It is easily possible--we do it every day in the lab--to synthesize a gene out of chemicals. I can make a human growth hormone gene. There is no way to tell the difference between the gene that I have made in the laboratory and the gene I would isolate from a human cell. Why is this somehow mystical? Why are genes

given a quality they don't have simply because they come out of human beings?

MOYERS: Many of us are raised with a sense of reverence for human life. We think of human beings as constituting a special, divine creation, and we're not certain about mucking around with it.

SINGER: We are special. And we are marvelous. ~~But~~ There are many living things in the world that are marvelous. How does it diminish our sense of ourselves to understand that we are the product of a lot of molecules coming together in a marvelous way? We are not those molecules, we are all of them together.

One of the things people very often mention in this context is the uniqueness of the individual, that each one of us is marvelously different from every other one. Modern genetics has told us that this is absolutely true. Except for identical twins, no two of us have the same DNA molecules. Biology says that each of us, with our different genetic makeup, is unique. It's the same splendid notion that we came to for a lot of other reasons--and biology underscores it. Knowing how we work in no way diminishes our uniqueness. It in no way changes how we look upon people we love. The physicist, Richard Feynman, asked why poets could write about Jupiter when they thought Jupiter was like a man? What kind of poet can't write about that same Jupiter if he knows that it's a great whirling sphere of methane and ammonia? You look out at the sky, and you look at Jupiter. It brings in all of us the same wonder, the same awe about the universe. I think the astronomer has more awe and wonder because he knows what it is that is up there. His knowledge doesn't diminish his awe ~~in him~~; it enhances it.

MOYERS: Do you think a biologist may have more awe and wonder for

the human body because he or she knows what's in there?

SINGER: I know that's true. My wonder at the kinds of things that we've learned in molecular biology beats anything that anybody can tell me in grand terms about how extraordinary a human being is. How incredible it is that a few changed genes have given us this tremendous gift of language, of communication, of being able to write down our history, of having culture, of drawing pictures, of making paintings. I think that I appreciate that more, not less, because of what I know.

MOYERS: Critics of genetic engineering say we are special as humans, but that doesn't give us the right to inflict suffering on the animals we're using for experiments. For example, right over here in Maryland, at the Agriculture Department's experimentation station, they have produced pigs that turn out to be pathetically arthritic and deformed creatures whose offspring are themselves deformed. The animal rights people say we don't have the right to do that to innocent creatures.

SINGER: It's very difficult to argue that we are special as human beings without also arguing that we ought to pay special attention to our own species. Within that special attention is the need to help those of our species who suffer from disease, starvation, and so forth. One of the best ways we have of trying to help that suffering is experimentation, learning new information about how living things work. For many of the questions we ask about living things, the only way that we have to answer them is to do a certain amount of experimentation on animals.

Now, there is no question but that work that has gone on in the past has sometimes misused animals unnecessarily. There is no question but that insufficient attention was paid to the lives and suffering of those animals. And there is no question but that we can still improve the way

we deal with experimental animals. But if we were to decide that we did not want to experiment on animals at all, we would not make advances in curing our own ills, or improving our own situation. We do a lot of things nowadays with cells that people used to do with animals. And there are other ways to replace animals for certain kinds of experimentation. But there are many things that we cannot do without animals.

MOYERS: So the animal rights people are not misguided in their concern?

SINGER: The animal rights people are misguided in some of their concerns, and in the extremes to which they go. But they also have a core message which has been important. Many people within the scientific community deal with the same questions that are raised by animal rights people, but approach them in rational, thoughtful ways that are not extreme, and that allow for a balance between our need to help our own special species, and our need to pay some attention to suffering animals.

MOYERS: How would you respond to the more severe critics of genetic engineering, like Jeremy Rifkin, who says we had better be very careful what we release into the environment, because we don't know enough yet about the unintended consequences. Genetic engineering ought to be done under only the most protected, sheltered, restricted circumstances imaginable.

SINGER: Let me say first of all that Jeremy Rifkin's view of the situation is a very extreme one. Not many people take his view, although we get the impression that they do because he is given a great deal of space on television, and in newspapers and magazines.

The release of organisms, which Rifkin still speaks about, was, of course, the crux of the earliest issue, and that was first raised not by Mr. Rifkin, but

by scientists, including myself, in 1973 and 1974. It was the basis of a discussion in the mid-seventies, which engaged the public, and which resulted in the development of very strict guidelines by the National Institutes of Health, guidelines which govern the way my colleagues and I ~~did~~ do experiments.

Now, Mr. Rifkin knows that very, ~~very~~ strict guidelines were put into place and that, as a consequence of a great deal of new scientific information, and consideration by scientists, ecologists, molecular biologists, and physicians, those guidelines have been relaxed. He also knows that there are still strict guidelines in place for those experiments that have the remotest possibility of being dangerous, that there is extensive review of experiments, and that there is extensive monitoring of what goes on. He is still crying about such things even in the face of a history of responsibility on the part of scientists and the government of which we can all really be proud. And one has ultimately to wonder why he is still crying about the safety issue when it has been addressed so extensively by so many people for so long.

MOYERS: It does seem that the scientific community, people like you, have been responsible over the last years in trying to come to grips with whatever possible dangers your experiments might pose. But you scientists are always coming up with difficult predicaments for society at large. Knowledge for knowledge's sake I happen to believe in, and that you have to follow curiosity wherever it goes. But the issues that come out of your research present us with very difficult choices. Example: What happens if businesses insist on screening prospective employees for their genetic code to see if they might be prone to certain diseases? What does this do to liability, to insurance costs, to the cost of doing business?

Society has to grapple with the consequences of your research. But, as you said in the beginning of this conversation, we are an illiterate political and social republic when it comes to scientific knowledge. How are we going to cope with the predicaments that you and your colleagues are handing us almost daily?

SINGER: I don't think that we--and now I say "we" because I am part of the public as well as being a scientist--are going to deal with these issues very effectively unless we are willing to learn something about science. Not every person needs to be a scientist. But there are some big ideas about the nature of the world that everyone ought to have as part of his baggage. People ought to know that we all get information in the form of DNA from our parents, and that our competence and our capabilities, both physical and mental, are to some extent dependent upon that. We all ought to know that if you take down a great deal of green stuff from the earth, you put less oxygen into the atmosphere. It's amazing that most people don't know that the oxygen isn't just up there for the taking, it's put there by living things called green plants. People somehow think the oxygen was there from the beginning. It wasn't.

We have to appreciate certain fundamental kinds of things if we're going to deal with these problems. And for the details, we're going to need to bring scientists into the discourse. The President's science advisor must give the President access to the best scientific information in the country, for health purposes, for environmental purposes, for defense, for weapons building--for all these things. Our success as a nation and the success of the planet as a whole depends on scientific discoveries, each of which hands us a new bag of problems. That's not very different from the way the world has always been. There's no free

lunch.

MOYERS: Except that we know so much more now than we did, and everything is so interconnected that every advance of knowledge creates a different kind of political and social dilemma.

SINGER: We are very ambivalent about it, aren't we? There's no question that people want the help with disease offered by genetic engineering. There's no question that people in our country will go for the latest device that improves the music they hear on their hi-fi sets. And yet there's the other side of it, the new problems that come from new knowledge. We have this ambivalence. The only way to deal with these problems is the hard way: look at them seriously, talk about them, and evolve a way to deal with them.

MOYERS: You really do feel that your work is based on human and humane values, don't you?

SINGER: I don't think that there is much happening on our globe that's more humane and more concerned with humanity than science.

MOYERS: Do you get mad at this image of the scientist as Frankenstein and Strangelove?

SINGER: Yes, I get angry with it.

MOYERS: What does it say to you?

SINGER: What does it say to me? It makes me angry with secondary school teachers because it makes me realize that a lot of wonderful, curious, bright young people are never going to have the privilege that I've had--to work for years without a boring day; to think of something new every day; to learn things that no one has ever known before, no matter how small it is. I myself have not learned big things in my own research. I'm not Watson or Crick or Weinberg, ~~for that matter~~. I learn

small things.

But to learn something one day that nobody ever knew before is something that everyone should have the chance to do. To the extent we're turning off young people in our country from scientific careers--quite apart from the fact that we're turning them off from wonderful careers in terms of good incomes and the availability of great jobs--we're turning them off from the possibility of sharing in this great world of discovery that scientists now have, that explorers no longer have because we've explored every nook and cranny on the planet, and we're not yet able to go to Jupiter or Mars. And if part of what turns them off is that they think that we scientists are somehow not part of the species, it's too bad.

MOYERS: You like your work, don't you, even if it means being ostracized at a cocktail party or a dinner?

SINGER: Oh, that's a fair bargain, as far as I'm concerned. I was a graduate student in 1953, when Jim Watson and Francis Crick announced what a DNA molecule looked like. They started an incredible forty years for biology. They allowed us to understand things about living organisms that as a graduate student I couldn't imagine. It isn't that the answers were unimaginable--the questions were unimaginable. So I've been part of an extraordinary time in biology. There hasn't been a day when I've wanted to do anything else.